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INTEGRATED STUDY MASTER'S THESIS

Treatment of Midshaft Clavicle Fractures in Adults

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1. Abbreviations

SC joint= Sternoclavicular joint

AC joint= Acromioclavicular joint

ORIF= Open Reduction and Internal Fixation

MIO= Minimally Invasive Osteosynthesis

PRISMA= Preferred reporting items for systematic reviews and Meta-Analyses

IMRAD= Introduction, Methods, Results and Discussion

DASH= The disabilities of the arm, shoulder and hand score

VAS= Visual analog scale

TEN= Titan elastic nail

3D-VR= Three-dimensional reconstruction and virtual reposition

BMI= Body Mass Index

ASA= American society of anesthesiologist's physical status classification

CTA= Computed Tomography Angiogram

OSS= Oxford Shoulder Score

EQ-5D= EuroQol five-dimension summary index

QALY= Quality Assessed Life Year

2. Keywords

Midshaft clavicular fracture, Treatment of midshaft clavicular fracture, Operative treatment of midshaft clavicular fracture, non-operative treatment of midshaft clavicular fractures, Treatment indications of midshaft clavicular fractures, Surgical treatment indications of midshaft clavicular fractures, non-surgical treatment indications of midshaft clavicular fractures

3. Summary

The clavicle is the most fractured bone in the human body. It is estimated that 2-10% of all the fractures in adults occur in the clavicle. Clavicular fractures involve the midshaft of the clavicle in four out of five cases. These fractures have been historically treated by conservative methods, but surgical treatment in recent years has become more popular. There are controversies in the literature about the optimal treatment method and indications of surgical treatment and conservative treatment to this day.

This literature review aims to summarize what current literature states about indications for operative versus non-operative treatment of midshaft clavicular fractures in adults and the current controversies related to treatment indications. The summarization is done through literature review by synthesizing pre-existing research data about the treatment indications of midshaft clavicular fractures in adults.

19 articles from PubMed and Cochrane library were included in this literature review.

The literature shows some controversies related to diagnostics of conditions like shortening or skin tenting and the optimal treatment method of different types of fractures is still not clear. The studies included in this literature review show good outcomes in both surgical and conservative treatment of the midshaft clavicle fractures and many authors suggest individualized treatment decisions according to patient characteristics. More studies are needed to improve the standardization of the indications and to definitively determine the optimal set of indications for surgical and conservative treatment of these fractures

4. Introduction

4.1.Anatomy of the clavicle

The two bones forming the shoulder girdle are the scapula and the clavicle. The clavicle connects the scapula to the sternum, so it serves as a connection between the upper limb and the axial skeleton. This connection allows a wide range of motion of the upper extremity by positioning upper limb far enough from the thorax.(1) The clavicle transmits forces that acts on the upper limb to the axial skeleton. (2) Also, the clavicle protects the nerves and the blood vessels in the upper part of the thorax travelling behind the clavicle. (1)

The clavicle is an S-shaped bone. The medial half of the clavicle is concave, and it forms the sternoclavicular joint (SC joint) with the sternum. The lateral half is convex, and it forms acromioclavicular joint (AC joint) with the acromion. (1) There are three regions in the clavicle: medial end, shaft and the lateral end. (2)

The clavicle can be divided into four different surfaces. Each of the surfaces has attachments sites for the musculature of the shoulder girdle. The muscles attached to the clavicle are responsible for a variety of different movements including stabilization of the scapula, depression of the shoulder, flexion, rotations and adduction of the humerus and rotation and flexion of the head. Superior surface is the attachment site for the anterior deltoid muscle and for the trapezius muscle. Inferior surface is the attachment site for the subclavius muscle. On the anterior surface, attaches clavicular part of the pectoralis major muscle and on the posterior surface attaches the sternocleidomastoid muscle and trapezius. (1)

Even though clavicle is classified as a long bone, it does not have medullary cavity like the long bones usually do. Its arterial blood supply is periosteal provided by the suprascapular, thoracoacromial and the internal thoracic artery. (1)

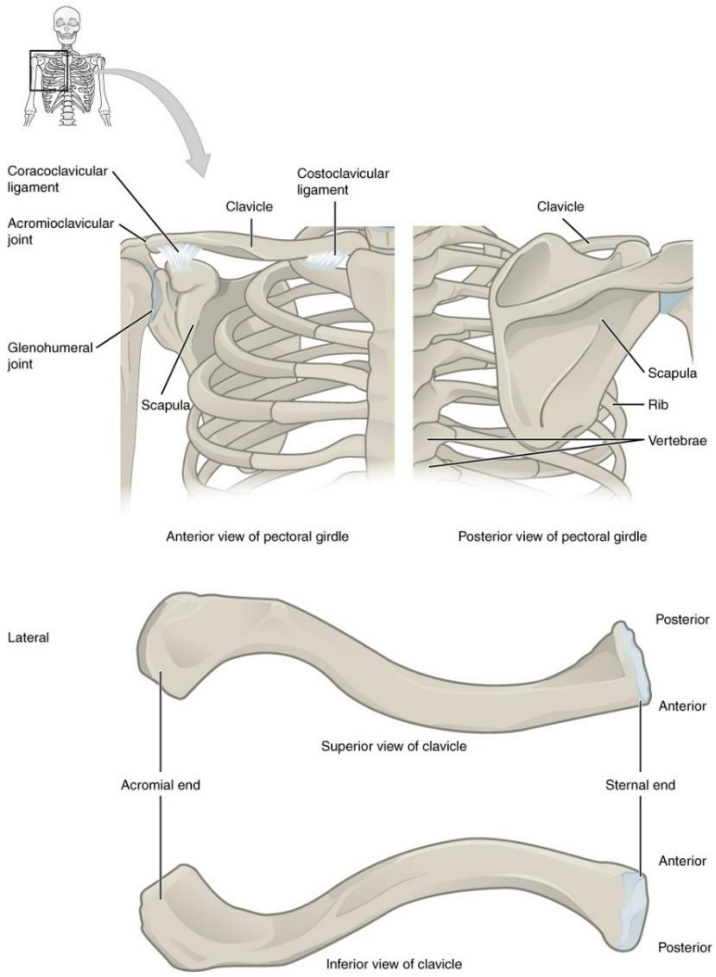


Figure 1. Anatomy of the clavicle.

Clavicle is a S-shaped bone located horizontally in the shoulder girdle. It forms AC- joint with acromion laterally and SC-joint medially with sternum.

4.2.Epidemiology of midshaft clavicular fractures

The clavicle is the most fractured bone in the human body.(2) Clavicular fractures involves the midshaft of the clavicle in four out of five cases. (3) It is estimated that 2-10% of all the fractures in the adults occur in the clavicle. (4) Risk for the clavicular fracture is highest amongst male patients younger than 30 years old and in the elderly patients older than 70 years old. (5) 50% of clavicular fractures are sports injuries. Fractures with high energy mechanisms, such as sports injuries or traffic accidents are more typical for young high-demanding males. The low energy fractures on the other hand are more common for elderly individuals as a result from falls. (6)

The trauma mechanism in clavicular fractures is usually either a fall on the outstretched hand or direct hit on lateral shoulder. Most commonly the middle or lateral part of the clavicle fractures due to fall force. This can be explained with the strong SC-joint, which rarely dislocates and therefore allows the clavicle to break from the force of falling. The complete fracture of the clavicle leads to a drop of the shoulder and the lateral clavicle portion. Musculature attached to the lateral portion of the clavicle pulls the lateral clavicle part anteriorly and medially. Because of the anterior displacement of the clavicle the nerves and blood vessels located posteriorly to clavicle usually are not affected by the clavicle fracture (2)

4.3.Treatment methods of midshaft clavicular fractures

Treatment methods of midshaft clavicular fractures can be divided into two groups: surgical treatment methods and conservative treatment methods.

There are several different classification systems for midshaft clavicle fractures. AO/OTA, Robinson and Neer classification systems of the midshaft clavicle fractures are most often used. They are all anatomical classification systems. (7) AO/OTA classification is used in this chapter to demonstrate the classification and treatment options of midshaft clavicular fractures.

The type of surgical approach for the treatment depends on the type of fracture. AO/OTA classifies the midshaft or diaphyseal clavicle fractures as simple fracture 15.2A, wedge fracture 15.2B and multifragmentary fracture 15.2C. (8) These fractures are not further subdivided into subtypes, but the configuration of the fragment may affect the treatment. (9)

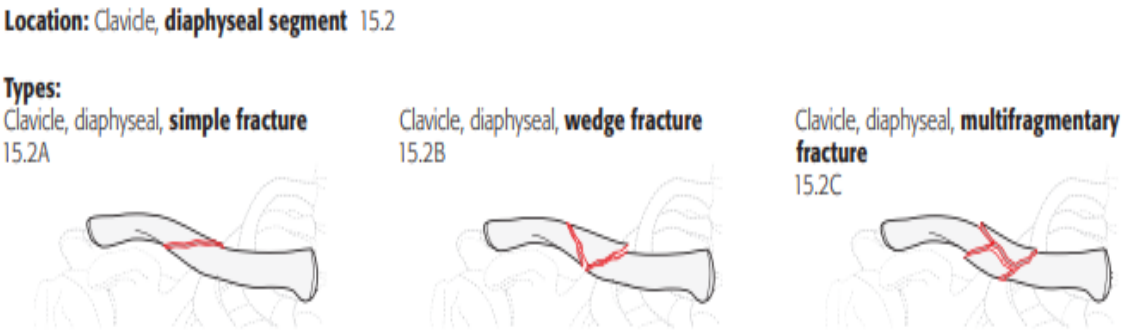


Figure 2. AO/OTA classification of the diaphyseal segment fractures of the clavicle.

The figure shows type 15.2A simple fracture, type 15.2B wedge fracture and type 15.2C multifragmentary fracture

Surgical methods for the treatment of midshaft clavicular fractures nowadays used according to AO-foundation guidelines are open reduction and internal fixation (ORIF)- lag screw with neutralization plate, ORIF- compression plate with lag screw, flexible intramedullary nail, ORIF- bridge plate and minimally invasive osteosynthesis (MIO)- bridge plate. The modality chosen for surgical intervention depends on different indications like the shortening of the clavicle, some fracture types and injuries to other structures such as neurovascular structures or other bones. Also patient related factors such as high demanding patient is supporting indication for surgical treatment (9)

Main indication in AO/OTA guidelines for the conservative treatment of the midshaft clavicular fracture is a fracture which has shortening and displacement less than 2cm and supporting indication is a situation where surgical interventions are not indicated. Conservative treatment is contraindicated in the situations in which there are indications for surgical treatment such as risk of skin penetration by bone, neurovascular injury or open fracture. (9)

Non operative or conservative treatment of midshaft clavicular fracture aims to restore the normal shoulder function with minimal deformity of the clavicle. Even though conservative treatment used to be golden standard treatment for the midshaft clavicular fractures historically, the treatment modalities according to literature are not uniform in conservative interventions. Treatment involves initially immobilization of the shoulder, but the evidence for the optimal technique of the immobilization and the duration of it is missing in the literature. (6)

AO/OTA suggests immobilization with sling that supports the upper arm and forearm close to the chest of the patient. This immobilization should be used full-time until week 7, from week 7 to 12 the weaning from the sling should be done and arm should be only immobilized during night and physical activity. Early movement of the arm is also suggested in these guidelines. (9) On the other hand some literature suggests immobilization with the figure of eight band to prevent secondary shortening of the fracture, however the literature does not support the superiority of either of these techniques. (6)

4.4.Need for literature review

The basis of conservative treatment being the golden standard treatment is 1960 study by Neer, which showed a very low rate of non-union in the conservatively treated midshaft clavicular fractures. Studies performed in recent years don't fully align with the previously conducted studies and they show higher rates of non-union and less satisfied patients when the treatment is conservative rather than operative. (10)

There are some indications for the operative treatment of the midshaft clavicular fractures that are considered to be evidence based in the literature, including: neurovascular injuries, severe displacement of the fractures, shortening of the clavicle more than 20mm, open fractures, floating shoulder and risk of skin penetration by the bone. (7) But the optimal treatment of the midshaft clavicle fractures remains unknown in the literature. As previously mentioned, the conservative treatment of midshaft clavicle fractures used to be the golden standard, but studies indicate that there is increased risk of malunion in this patient group compared to surgically treated patients. On the other hand, studies show that outcomes in the surgically treated patients are similar to those treated conservatively after 1 year, but the rate of complications is higher in this group compared to conservatively treated patients. (11)

Because of the uncertainty about the optimal treatment and indications for different treatment modalities, a literature review is needed to track the concepts in the current literature about indications for operative vs non-operative treatment of midshaft clavicular fractures.

4.5.Aim of the thesis

This literature review aims to summarize what current literature states about indications for operative versus non-operative treatment of midshaft clavicular fractures in adults and the current controversies related to treatment indications. The summarization is done through literature review by synthesizing pre-existing research data about the treatment indications of midshaft clavicular fractures in adults.

5. Research methods

5.1. Literature review

Narrative review and systematic review are the two forms of standard literature review. Both aim to synthesize pre-existing research data. The main goal of the systematic review is to formulate a well-

defined research question and to provide analyses of the evidence. This is done using guidelines like Preferred reporting items for systematic reviews and Meta-Analyses (PRISMA). Narrative reviews on the other hand do not have acknowledged guidelines and that is why it is usually a more subjective form of literature review. Narrative review is used when broader scope is needed for the review and it is more often used for tracking development of clinical concepts, when rules of the systematic review might be too restricting. Even though there is no strict guidelines for the narrative review, the preferred structure for the narrative reviews is IMRAD (Introduction, Methods, Results and Discussion) (12)

5.2. Literature search

The literature search was performed in November 2024. The search was conducted in the PubMed and Cochrane Library databases. The key words used in the search were: ''Indications for operative and non-operative treatment of midshaft clavicular fractures'' OR ''Operative vs non-operative management of midshaft clavicular fractures'' OR ''surgical vs non-surgical treatment of midshaft clavicular fractures'' OR ''treatment indications of midshaft clavicular fractures.''

The inclusion criteria in search of the articles were: the article was published between 2014 and 2024 to ensure relevance; free full article is available, and all types of articles were included. With this search 22 articles were found from PubMed and 2 articles from the Cochrane Library, totaling 24 articles. After removing the duplicates, 23 articles remained.

All the abstracts were read, and 21 article remained for the review of the full article by using the following exclusion criteria: article not available in English, full text not available, not related to adult population, not related to midshaft clavicular fractures and articles not related to treatment indications. 2 Articles were excluded because they were not related to adult population.

After reviewing a total of 21 full articles, 19 articles were included in the literature review. Articles were excluded using the previously mentioned exclusion criteria. Flow diagram was made from the literature search using the PRISMA 2020 flow diagram.

Inclusion criteria	Exclusion criteria
The article was published between 2014 and 2024	Article not available in English
Free full article is available	Full text not available
All types of articles were included	Not related to adult population
-	Not related to midshaft clavicular fractures
-	Not related to treatment indications

Figure 3. Table of inclusion criteria and exclusion criteria.
These criteria were used in the literature search for literature review.

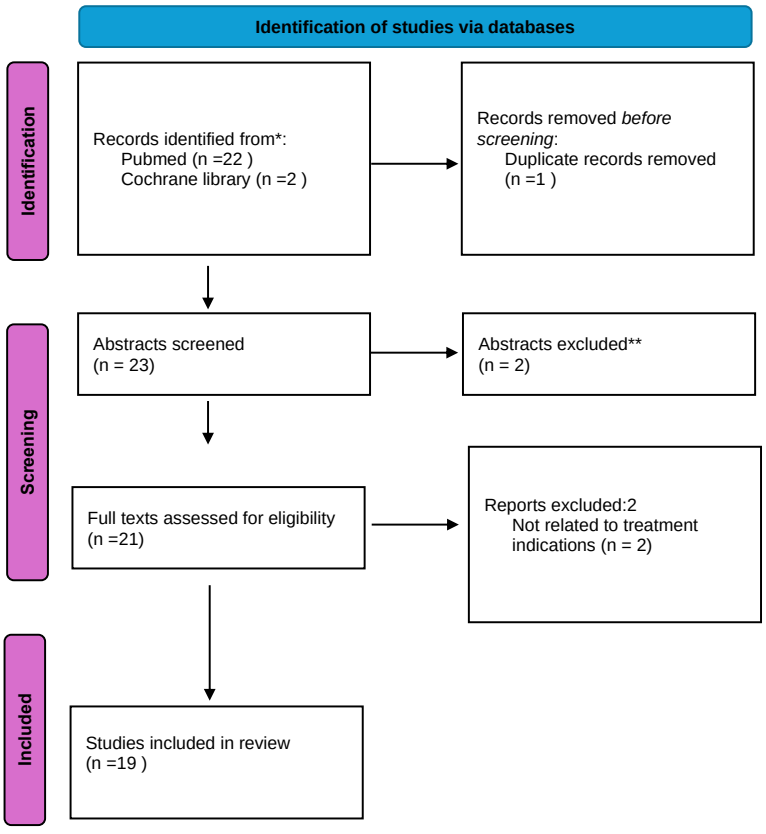


Figure 4. Identification of studies via databases visualized with PRISMA flow diagram.
The diagram shows 24 records identified from the databases and the screening process of the identified literature. 19 studies were included in review after the screening process.

6. Results

6.1. Regular indications for surgical treatment mentioned in the literature

Regular indications for surgical treatment named in various sources are shoulder impaction, floating shoulder, open fracture, and fracture with neurovascular complications. Also risk of skin perforation, comminuted fracture, shortening of fracture by >20mm and symptomatic nonunion are mentioned in the literature as indications for the surgical treatment. It's also mentioned that decision making related to these indications should be considered individually by patients' activity, age and concomitant injuries. (4,5,7,9,13,14)

According to 2023 review article by von Rüden et al. surgical treatment has no additional benefits for quality of life compared to conservative treatment. Therefore, it should be only considered when there are additional complications with fracture including risk of skin perforation, comminuted fractures, open fractures, floating shoulder or severely displaced fracture. (7)

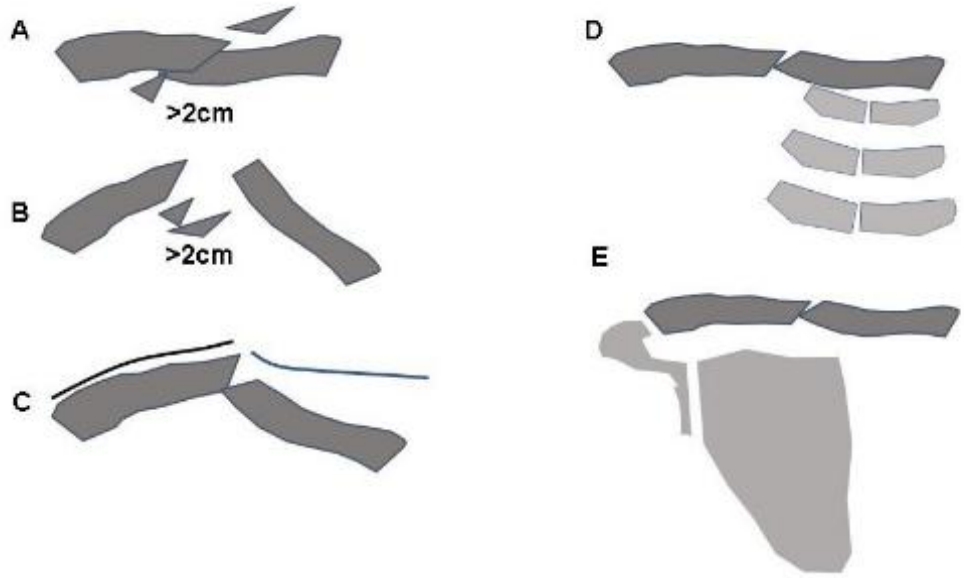


Figure 5 Operative treatment indicated in following fracture types(6)

A >2cm shortening
B Displaced without cortical contact >2cm
C Skin tenting
D Fracture with ipsilateral serial rib fractures
E Floating shoulder

6.2. Non-operative treatment indications

2018 published review article by Waldmann et al states that there is no controversy that nondisplaced fractures and cortically aligned fractures can be successfully treated by conservative treatment methods. Also, non-operative measures for treatment are recommended in fractures with shortening less than 2cm. With these indications more than 50% of midshaft clavicle fractures should be treated conservatively. (6) Conservative treatment in non-displaced and minimally displaced fractures is superior to surgical treatment and should be considered as the golden standard according to 2023 published review article by von Rüden et al.(7)

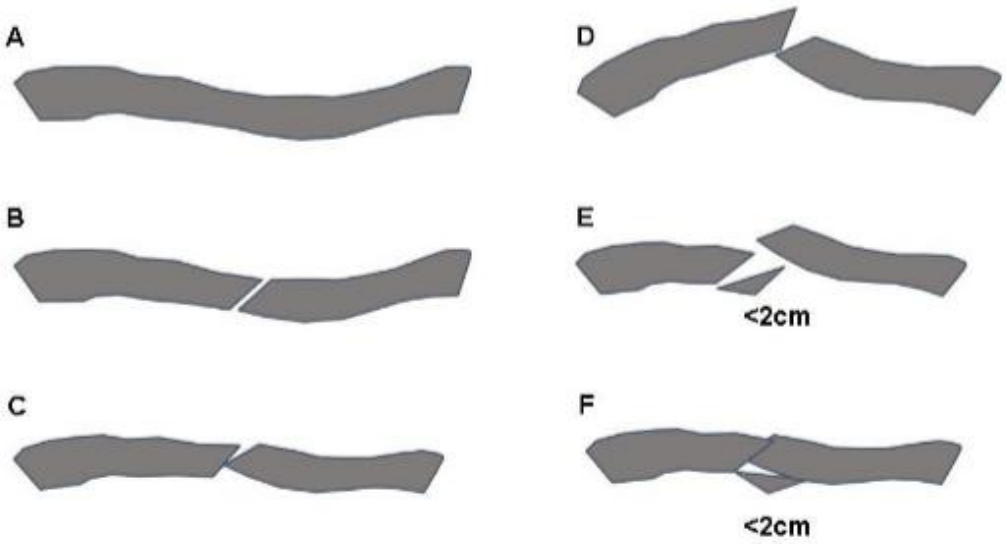


Figure 6 Conservative treatment indicated in following fracture types(6)

A Incomplete fracture
B Alignment
C Minimal displacement
D Dislocated fracture with cortical contact
E Displaced fracture with distance <2cm
F Shortening <2cm

6.3. Displacement and shortening of the clavicle

It is still controversial in literature if conservative or operative treatment is optimal for fractures with shortening >2cm and displacement. (6) Current beliefs are that shortening increases risk of nonunion if treated conservatively and also shortening is thought to lead to worse functional outcomes after union. (15)

6.3.1. Outcomes in treatment of the fractures with displacement and shortening

Systematic review by Woltz et al in 2017 aimed to evaluate the literature to determine if the clavicular shortening due to non-anatomical healing during conservative treatment of displaced clavicular fractures is negatively associated with shoulder function. The study was done to clarify if there is sufficient evidence to support shortening of clavicle as an indication for the surgical treatment. The previous studies has shown controversial results showing both worse outcomes if shortened clavicle is treated conservatively and no association with shoulder function. (15)

Systematic review included 6 studies with 379 patients. The studies were published between 2006 and 2015. Most of the fractures were immobilized with either sling or figure-of-eight band. (15)

Different measurements were used in the studies to define clavicular shortening. Some studies used the difference between fractured clavicular and contralateral clavicle to measure shortening. Also, proportional shortening was used, where the overlap of the fracture was divided by the sum of the length of the injured clavicle and overlap. Three studies compared outcomes if shortening was less than 20mm to more than 20mm and one study used 15mm as cut-off value.(15)

Outcomes were measured with DASH scores (The disabilities of the arm, shoulder and hand), Constant scores or by arm strength. In three of the studies included there was no statistically significant difference in shoulder function and shortening measured with DASH score. In four of the studies no significant difference was found in the association between constant scores and shortening. Also shortening >20mm did not result in statistically significant decrease in Constant score. The evaluation of the arm strength found no statistical significance between shortening and shoulder motions, except for decreased abduction endurance. These results are shown in **figures 7 and 8.** (15)

References	Mean shortening in mm (SD)	Mean Constant score (SD)	Mean DASH score (SD)	Correlation (r) or p value
Fuglesang et al. [26]	17.1 (7.1)	81 (69–90) (median)	6.7 (0.8–19) (median)	
	<15 mm: $n \approx 30$	80 (64–88)	7 (3–27)	$p = 0.5$ (constant)
	>15 mm: $n \approx 30$	84 (74–90)	7 (0–11)	$p = 0.1$ (DASH)
Figueiredo et al. [27]	9.2 (6.4)	N/A	3.38 (9.21)	$r = -0.017$; $p = 0.90$
	<20 mm: $n = 47$ (81%)		3.38 (CI 9.56)	$p = 0.53$
	>20 mm: $n = 11$ (19%)		3.33 (CI 7.02)	
Rasmussen et al. [24]	11.6 (8.2)	86.3 (29–100)	N/A	$r = 0.14$; $p > 0.05$
	<20: $n = 116$ (85%)	7.2 (10.3)[a]		$p = 0.79$
	>20: $n = 20$ (15%)	7.9 (10.3)		
Postacchini et al. [25]	Males: 14.1 (8.9);	Allman 1B[c]: 87.1	N/A	
	8.9% (5.6%)[b]	Allman 1C: 85.6		
	Females: 10.9 (7.8); 8.3% (6.0%)[1]	CS ≥ 90 ($n = 55$): 7.7%		$p < 0.05$
		CS ≤ 80 ($n = 9$): 13.2%		
McKee et al. [5]	14.5 (8.6)	71 (SD not given)	24.6 (SD not given)	$r = -0.20$; $p = 0.44$
				$r = 0.32$; $p = 0.11$
	<20 mm: $n = 19$ (63%)			$p = 0.06$
	≥20 mm: $n = 11$ (37%)		DASH > 30 points:	
			3/19 (16%)	
			7/11 (64%)	

[a] Mean difference in Constant score between injured and uninjured shoulder

[b] Proportional shortening: overlap of fracture fragments divided by sum of overlap and length of injured clavicle

[c] Allman type 1B: displaced fractures, Allman type 1C: displaced with third bone fragment

Figure 7. Relation of clavicle shortening with Constant and DASH scores (15)

References	Mean shortening in mm (SD)	Mean strength in Newton (95% CI)	Correlation or p value
Stegeman et al. [23]	25 (16)	Adduction: 7.2 (−3.5 to 18)[b]	$\beta = -1.29$ ($p = 0.07$)
	13% (8%)[a]	Abduction: −0.1 (−8.8 to 8.6)	$\beta = -0.47$ ($p = 0.4$)
		Anteflexion: 9.6 (−3.1 to 22)	$\beta = 0.59$ ($p = 0.5$)
		Retroflexion: 14.6 (−6.7 to 9.8)	$\beta = -0.08$ ($p = 0.9$)
		Exorotation: 2.0 (−3.2 to 7.3)	$\beta = 0.08$ ($p = 0.8$)
		Endorotation: 5.1 (−0.8 to 11.1)	$\beta = 0.37$ ($p = 0.3$)
McKee et al. [5]	14.5 (8.6	Flexion: 81%, 75%[c]	ns
		Abduction: 82%, 67%	$r = -0.32$ ($p = 0.06$)
	<20: $n = 19$ (63%)	Exorotation: 81%, 82%	ns
	≥20: $n = 11$ (37%)	Endorotation: 85%, 78%	ns

[a] Proportional shortening: overlap of fracture fragments divided by sum of overlap and length of injured clavicle

[b] Difference in strength between uninjured and injured shoulder. $p > 0.05$ for all comparisons

[c] Strength and endurance of injured shoulder as a percentage of the uninjured shoulder

Figure 8. Relation of clavicle shortening with shoulder strength(15)

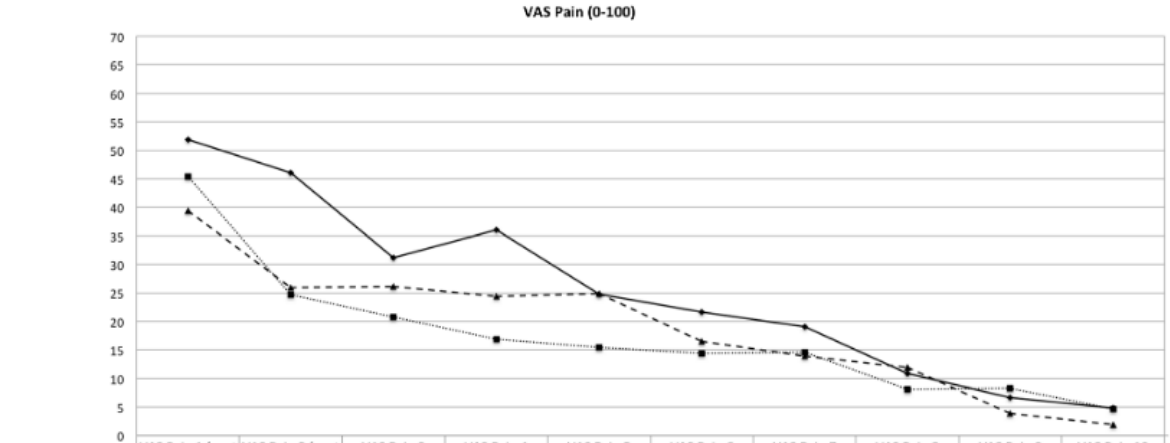
Woltz et al. concludes that existing evidence does not support using shortening of the clavicle as surgical indication with goal of better functional outcome. Other goals of surgical treatment such as reducing risk of nonunion and earlier recovery should be further studied. (15)

Eden et al aimed to compare results of the different treatment methods of the midshaft clavicle fracture in the prospective study published in 2015. The treatment methods in comparison were conservative treatment with rucksack band and operative treatment with either titan elastic nail (TEN) or by plate fixation of the fracture. (10)

The study included 102 patients with displaced midshaft clavicle fracture classified as either Robinson type 2B1(displaced midshaft fracture, Simple or wedge comminuted) or 2B2(displaced midshaft fracture, isolated or comminuted segmental) fracture. The patients were able to choose either surgical or conservative treatment. 2B2 fractures were mainly treated by plate fixation and 2B1 with TEN. 37 patients were treated conservatively with rucksack bandages for 4 to 6 weeks, 41 patients were treated with plate fixation and 24 with TEN. (10)

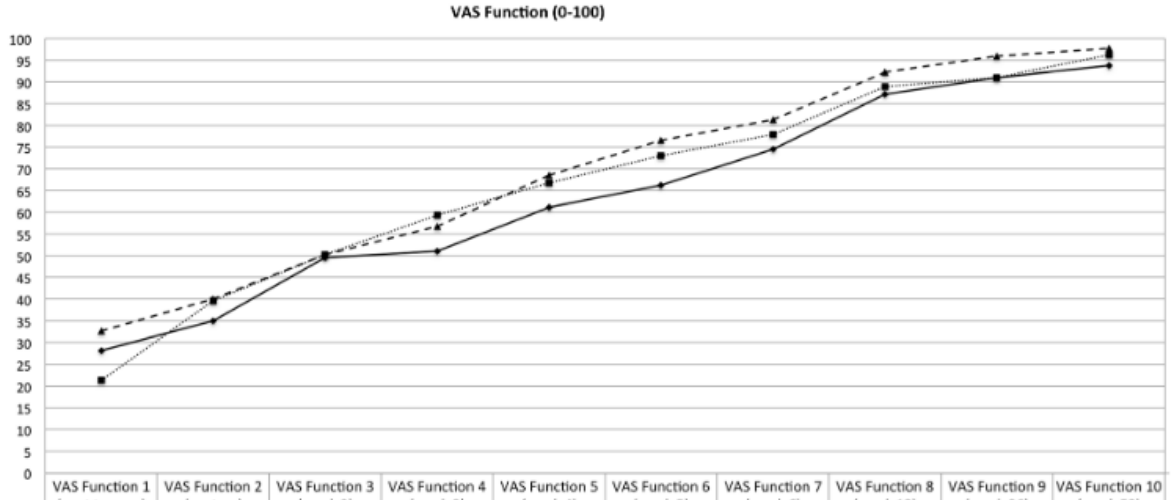
The evaluation of pain and function was done with visual analog scale (VAS), evaluation of function with DASH- score and strength measurement with Constant Murley Score. Also, the time away from work and complications were evaluated. The follow-ups for the study were done weekly for the first 6 weeks and after that on weeks 6, 12, 26 and 52.(10)

Study showed that all the previously mentioned treatment modalities lead to good or excellent clinical outcomes after 1 year. The operative treatment was superior to conservative treatment in some aspects evaluated. The pain reduction was statistically significantly superior in plate fixations early postoperative phase (weeks 1-5) compared to conservative treatment ($p<0.05$), but after 52 weeks there was no statistical significance in the pain reported between the patient groups. Both TEN and plate fixation showed significantly better VAS function compared to conservative treatment at 1 year, but in more objective DASH score there was no significant difference when it comes to arm function after the treatment. Constant Murley Score was significantly better in TEN group than in the plate fixation or conservatively treated group during the whole follow up process. (10)



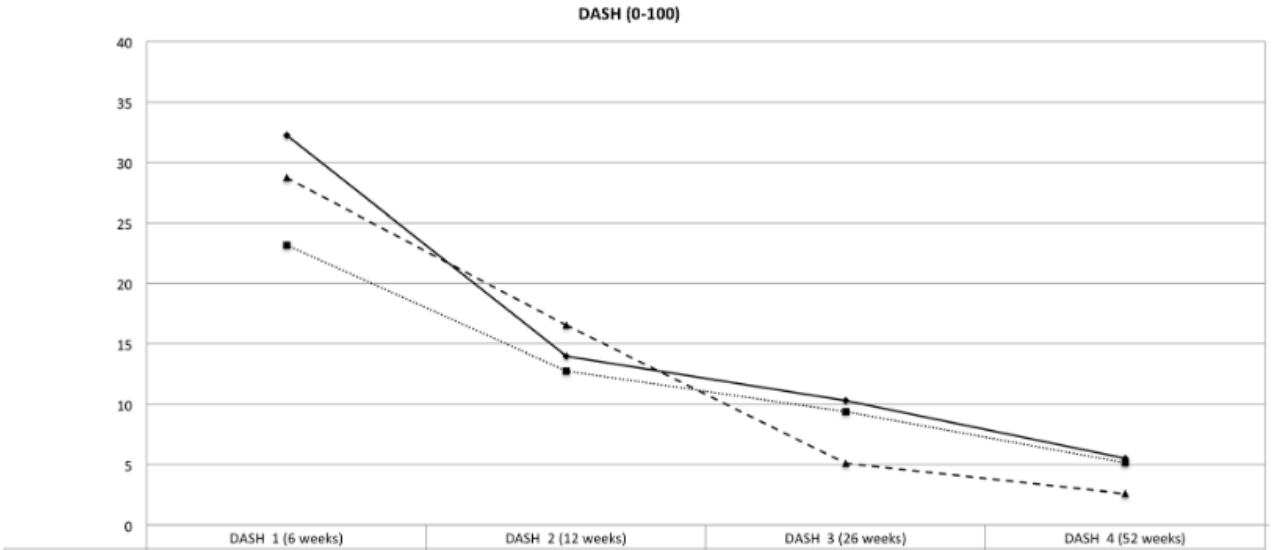
	VAS Pain 1 (post trauma)	VAS Pain 2 (post Op)	VAS Pain 3 (week 2)	VAS Pain 4 (week 3)	VAS Pain 5 (week 4)	VAS Pain 6 (week 5)	VAS Pain 7 (week 6)	VAS Pain 8 (week 12)	VAS Pain 9 (week 26)	VAS Pain 10 (week 52)
non-op	52	46	31	36	25	22	19	11	7	5
Plate	45	25	21	17	15	14	15	8	8	5
TEN	39	26	26	24	25	17	14	12	4	2
non-op vs Plate	0,25	0,00	0,02	0,00	0,09	0,02	0,10	0,60	0,88	0,11
non-op vs TEN	0,10	0,01	0,49	0,08	0,90	0,17	0,17	0,90	0,25	0,06
Plate-TEN	0,38	0,94	0,20	0,16	0,15	0,66	0,85	0,54	0,34	0,75

Figure 9. shows VAS pain scoring during the 52-week period after the fracture. (10)



	VAS Function 1 (post trauma)	VAS Function 2 (post op)	VAS Function 3 (week 2)	VAS Function 4 (week 3)	VAS Function 5 (week 4)	VAS Function 6 (week 5)	VAS Function 7 (week 6)	VAS Function 8 (week 12)	VAS Function 9 (week 26)	VAS Function 10 (week 52)
non-op	28	35	50	51	61	66	74	87	91	94
Plate	21	40	50	59	67	73	78	89	91	96
TEN	33	40	50	57	69	77	81	92	96	98
non-op vs Plate	0,27	0,54	0,94	0,07	0,16	0,05	0,32	0,74	0,47	0,03
non-op vs TEN	0,36	0,61	0,98	0,38	0,12	0,02	0,21	0,20	0,05	0,01
Plate-TEN	0,42	0,99	0,95	0,47	0,87	0,72	0,80	0,26	0,17	0,43

Figure 10. Showing the VAS function scores scoring during the 52-week period after the fracture. (10)



	DASH 1 (6 weeks)	DASH 2 (12 weeks)	DASH 3 (26 weeks)	DASH 4 (52 weeks)
non-op	32	14	10	6
Plate	23	13	9	5
TEN	29	17	5	3
non-op vs Plate	0,11	0,66	0,63	0,44
non-op vs TEN	0,27	0,90	0,14	0,44
Plate-TEN	0,45	0,64	0,27	0,97

Figure 11. shows DASH scores recorded during the 52-week period after the fracture. (10)

Both surgical treatment methods significantly decreased the time away from work. The conservative treatment group had 9.4 weeks of leave from work and the plate fixation group had 6.2 weeks and TEN group 4.5 weeks, averaging 5.6 weeks in surgical treatment group. (10)

One revision surgery due to lateral tear out of the plate was performed in the plate fixation group. In TEN group one plate fixation was performed due to non-union after TEN and two dislocations of the nail were recorded. In the conservatively treated group two non-unions were recorded. (10)

Study shows that plate fixation was the most secure method to achieve bone healing. Also, plate fixation had significant reduction of the pain during the first 5 weeks postoperatively compared to other methods. The results for 1 year follow up however raise a question about necessity of the surgical treatment as the perceived pain and functional score DASH was similar in the conservatively treated group. TEN performed best in all statistics recorded, but as a disadvantage it requires the removal of the nail after 6 months. Excellent results with TEN were partly due to less severe Robinson 2B1 fractures. It seems like surgical treatment of these fractures has advantages over conservative treatment; TEN in Robinson 2B1 fractures shows better objective and subjective functional outcomes and plate fixation in Robinson 2B2 has the best reduction of pain during early postoperative weeks. (10)

Hulsmans et al. published a prospective study in 2016 which compared intramedullary nail fixation and plate fixation in the treatment of displaced midshaft clavicle fractures. The aim of the study was to see which method leads to less disability, which method is related to more frequent complications and implant removal and which method is associated with more complications after the 1st postoperative year. (16)

The study investigated prospectively a population from previously done multicenter randomized controlled trial, which compared outcomes of intramedullary nail fixation to plate fixation for 52 weeks postoperatively. The patients of the previous study were contacted to survey the outcomes, the mean follow-up was 39 months. The survey included QuickDASH score for upper extremity disability, questions about implant related irritation and questions about complications and interventions required postoperatively. (16)

QuickDash scores had only marginal improvement after 12 months of follow-up. There was no significant difference between QuickDash scores between intramedullary nail and plate fixation group. In both groups the long-term functional outcome seemed to be excellent. Intramedullary nail group had higher risk of implant removal, but there was no significant difference in proportion of groups having implant related irritation. After 1 year to final follow-up at 39 months there was no major complications in either of the groups, the complications reported were implant irritation and cold intolerance and the prevalence of these had no significant difference between the two groups. (16)

Followup	Plate fixation (n = 56)† (mean/SD)	Intramedullary fixation (n = 62)‡ (mean/SD)	Mean difference (95% CI)	p Value
1.5 months	11.8 (12.1)	16.1 (14.0)	−4.3 (−9.2 to 0.5)	0.080
3 months	5.1 (7.2)	9.4 (11.6)	−4.3 (−7.9 to 0.6)	0.023
6 months	2.9 (5.1)	5.6 (9.9)	−2.7 (−5.8 to 0.4)	0.092
12 months	2.6 (5.2)	4.0 (9.8)	−1.4 (−4.4 to 1.6)	0.347
39 months	1.8 (3.6)	1.8 (7.2)	−0.7 (−2.2 to 2.0)	0.945

Figure 12. showing results of QuickDash scoring from 1.5months to 39 months follow-up. No significant difference in function according to QuickDash in long-term follow-up. (16)

Classification	Plate fixation (n = 56)† Number (%)*	Intramedullary fixation (n = 62)‡ Number (%)*	Relative risk (95% CI)	p Value
Implant related irritation	39 (70)	41 (66)	1.05 (0.8–1.4)	0.683
Implant removed	28 (50)	51 (82)	0.61 (0.5–0.8)	< 0.001**
Reason removed				0.551
Attributable to implant-related irritation	21 (75)	35 (69)	1.09 (0.8–1.5)	
Patient's wish or surgeon's preference	7 (25)	16 (31)	0.80 (0.4–1.7)	
Status not removed				0.939
No irritation	10 (36)	5 (45)	0.79 (0.4–1.8)	
Experiencing irritation, but implant removal not necessary	8 (29)	3 (27)	1.05 (0.3–3.2)	
Experiencing irritation, but no request for removal owing to fear of reoperation	4 (14)	1 (9)	1.5 (0.2–12.5)	
Experiencing irritation, considering removal	6 (21)	2 (18)	1.2 (0.3–5.0)	

Figure 13. Implant related problems according to the questionnaire. Significant difference in removal rate between intramedullary and plate fixation groups. (16)

The study showed that long-term functional outcomes after intramedullary nail fixation and plate fixation were excellent. Intramedullary fixation was more prone for implant removal due to irritation. The authors suggest longer follow-up periods postoperatively due to implant related irritation even after 12 months from operation. (16)

A retrospective study published 2019 by Micheloni et al. aimed to compare clinical outcomes of surgical and conservative treatment of displaced midshaft clavicle fractures and to evaluate incidence of complications including pain, scarring, patient satisfaction and shoulders range of motion. The study included 87 adult patients with AO 15.2A fractures (see **Figure 2**). 50 patients were treated by plate fixation and 37 patients conservatively. The evaluation of the outcomes was done by measuring DASH and constant scores. To evaluate complication rate in conservative treated patients and patients treated by plate fixation following variables were evaluated: pain, anatomical defects, surgical wound problems, delayed union and malunion and secondary fractures. (5)

In DASH and constant scores there was no statistically significant difference between the two groups. There was a higher complication rate in the conservatively treated group. 39.5% of conservatively treated patients were unsatisfied with aesthetics of the shoulder after the treatment, the same percentage was 12% in surgically treated patients. 13.9% of conservatively treated patients had to be operated because of malunion and 20% of surgically treated patients needed secondary surgery to remove implants. (5)

The plate fixation therefore didn't result in better functional outcomes, but it decreased the risk of nonunion. The authors suggest individualized treatment according to patients' functional demand and fracture characteristics. Younger patients may benefit from faster recovery from surgery and conservative treatment is still good option for the less active elderly people with contraindications for surgery. (5)

Naessig et al describes full functional recovery from conservative treatment of comminuted displaced fracture in their 2022 published case report. The patient met the surgical treatment criteria but wanted the fracture to be treated conservatively. (4)

The patient in the case report was 58 years old male. The left clavicle was fractured in a bicycle accident. During the initial examination there was deformity of the left shoulder with skin tenting. No signs of neurovascular damage associated with fracture were present. X-ray showed displaced comminuted fracture of midshaft of the left clavicle, also there was nondisplaced fractures of left 4th to 6th rib. (4)

Figure 14. Baseline X-ray showing comminuted and displaced fracture of midshaft of the left clavicle (4)

Surgical treatment was indicated with this type of injury and patient was informed that there is high risk of malunion without surgery. Patient refused the surgical treatment and conservative treatment with sling immobilization was started. (4)

There were regular follow-ups during the conservative treatment with guidance on the rehabilitation of the shoulder. On the last follow up on the 3rd month patient X-ray showed callus formation on the fracture and well healing rib fractures. In physical examination there was a painless deformity of the left clavicle area and full range of motion of the injured shoulder and strength equal to the contralateral shoulder. The patient was able to return to previous activities with completely recovered shoulder function. The authors hypothesize that the good healing of the clavicle was due to patient's previous active lifestyle and compliance to rehabilitation. (4)

Figure 15. X-ray after 3months from the injury showing the healing process of the fracture and shortening of the clavicle (4)

6.3.2. How the clavicle shortening is measured

The determination of the clavicle length before the fracture remains as unsolved problem in literature. To use the shortening of the clavicle as a surgical indication, it is fundamental to be able to define the shortening with accurate measurements. There are multiple different ways to calculate the shortening. Measurements might be done with tape measures, plain x-rays or computed tomography imaging. Comparing the fractured clavicle length to the unfractured contralateral clavicle length are still used for the measurement of the shortening, but not recommended, as studies show that in the same individual the clavicle lengths might differ up to 15 to 20mm. (13,17)

Archer et al made a retrospective study in 2016, which aimed to identify correlations between computed tomography and plain X-ray measurements of shortening in displaced midshaft clavicle fractures.(13)

The study included 22 patients whose X-rays and computed tomography images after displaced midshaft clavicle fracture were reviewed at time zero and 2 weeks later. Shortening measured in CT and plain X-ray were then compared. The study had an assumption that clavicle lengths are symmetrical and the unfractured clavicle length was used to represent the normal clavicle length of the patient. Shortening was calculated by subtracting the fractured clavicle length from the normal clavicle length. (13)

The study found that measurement of shortening did not correlate with plain X-ray measurements. The error in plain film measurements was up to 6.96 cm. This study showed that plain x-ray measurements don't reliably show shortening of the clavicle. The accuracy of patient selection for surgery can be improved by computed tomography measurements of the shortening. (13)

Assumption that the clavicles are symmetrical might lead to over or undertreatment if the clavicles are asymmetrical. 2023 published retrospective study including 100 patients by Ergişi et al. aimed to investigate whether assumption on the symmetric clavicle length is valid and to evaluate factors predicting clavicle asymmetry. (11)

The study was done by obtaining thoracic computed tomography images taken for any reason in the author's institution. Clavicle lengths were then measured by orthopedic surgeons from 3D reconstructions of the images. The length difference was calculated by subtracting the length of the shorter clavicle from the length of the longer clavicle of each patient. (11)

The study showed that the mean clavicle length in this adult population was 13.9±1.3cm on the right and 14.1±1.2cm on the left ($p < 0.001$). The mean difference of the length was 4.0±3.3cm. Female patients had shorter clavicles than the males on both sides with statistical significance. There was no statistical significance on the mean difference on the lengths between the male and female patients. Also, the age didn't affect the length difference. (11)

TABLE I

Clavicular asymmetry according to sex and age

	≤5 mm (n=71)			>5 mm and ≤10 mm (n=23)			>10 mm (n=6)			
	n	%	Mean±SD	n	%	Mean±SD	n	%	Mean±SD	*p*
Age			63.3±16.4			62.7±13.5			70.3±10.1	0.550
Sex										0.859
Male	44	72.1		13	21.3		4	6.6		
Female	27	69.2		10	25.6		2	5.1		

SD: Standard deviation.

Figure 16. Table showing the clavicular asymmetry according to age and sex (11)

29% of the patients had more than 5mm of clavicle asymmetry and 6% more than 10mm. According to Ergisi et al clavicle symmetry is not valid assumption when calculating the shortening of the fractured clavicle for the surgical treatment of midshaft clavicle fractures. Using the contralateral asymmetric clavicle in the shortening calculations might lead to over or undertreatment of the midshaft clavicle fractures. (11)

Öztürk et al studied the accuracy of three-dimensional reconstruction and virtual reposition of bone fragments (3D-VR) in measurement of the clavicle shortening. The objective of the study was to determine the accuracy of 3D-VR using synthetic bone models and to assess correlations between 3D-VR and traditionally used 2D measurements in the patients with midshaft clavicle fracture. (17)

First the 3D-VR measurement accuracy was studied on synthetic bone models. These synthetic bone models were then measured by metric caliper to establish the length of the models and afterwards computed tomography images were taken from the models and measurements were done using 3D-VR on the models. The clinical study itself was retrospective study using hospital database to review polytrauma patients who had midshaft clavicle fracture and imagine done using computed tomography and AP clavicle X-ray. (17)

The shortening of midshaft clavicle fractures was measured on roentgenographs by using 4 methods described in the literature. These methods are described in **Figure 17.**

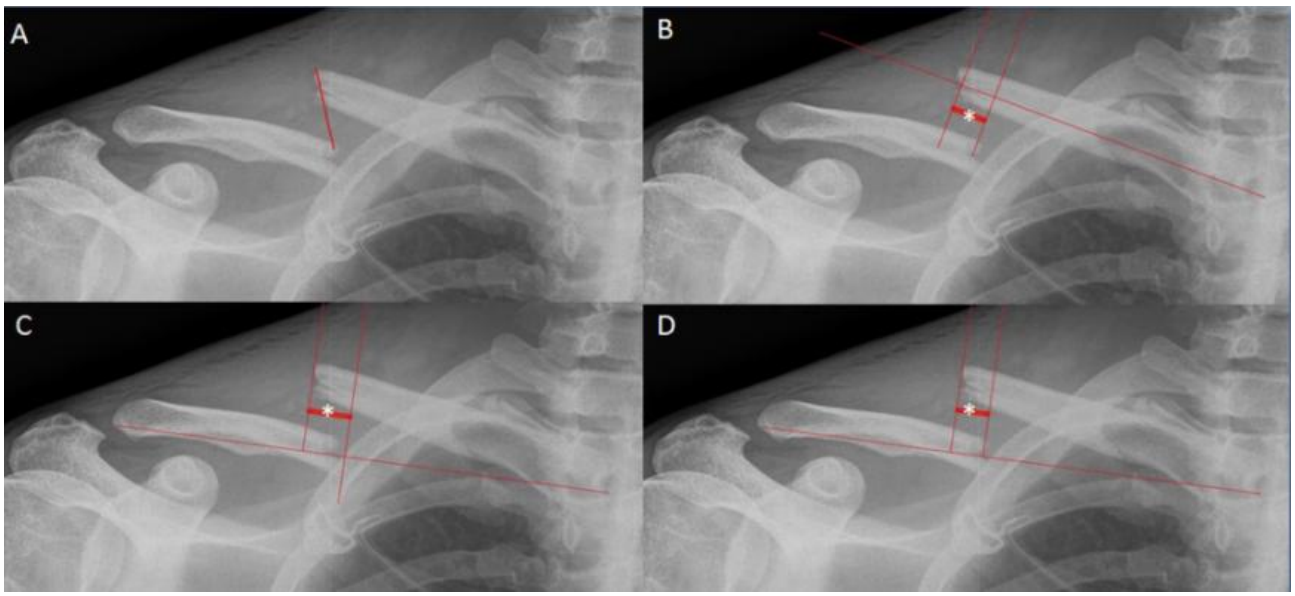


Figure 17. Methods described in the literature used to measure shortening on the roentgenographs of the clavicle(17)

A) Jeray et al	Measures the distance between reduction points on each fragment.
B) Silva et al	Draw a straight line running through the middle of each broken piece. Then, draw lines perpendicularly to those, passing through the ends of the pieces, and measure the gap between those perpendicular lines.
C) Smekal et al	Draw one straight line along the full length of the broken clavicle, then measure the distance between two perpendicular lines that touch the furthest points of each broken piece.
D) HUG method	Measures the distance between two perpendicular lines to the clavicle's axis passing through two reduction points on each fragment.

On synthetic bones the difference between measurements on the 3D-VR and manual measurements was 0.736mm with no statistical significance p=0.56. The clinical on study on the patients included 19 patients with midshaft clavicle fractures with previously mentioned imagine studies done. The methods by Jeray et al. and Smekal et al. had statistically significant difference on the measurements compared to computed tomography measurements by 11.95mm and 9.28mm. The HUG method and method by Silva et al. had no statistically significant difference compared to computed tomography measurements.(17)

According to the results from this study, 3D-VR is accurate in measuring the shortening of midshaft clavicle fracture. From the 2D roentgenographic measurement methods the method by Silva et al and HUG method correlated with the measurement accuracy of the computed tomography method.

The authors concluded that the computed tomography imaging to measure the shortening of the midshaft clavicle fracture is recommended when available. If the 2D roentgenographic measurements are used, the preferred methods are the HUG method and the method described by Silva et al. (17)

6.4. Vascular injury related to fracture

Typically, vascular injury associated with midshaft clavicle fracture is considered as an indication for surgical treatment of the fracture. This is because the general principle in vascular injuries related to fractures is to stabilize the fracture before repairing the damaged vasculature, to avoid failure of the vascular graft from tension.(18) AO/OTA for example suggest neurovascular injury as a contraindication for conservative treatment for midshaft clavicle fractures. (9)

In the literature search for this literature review one study fulfilling the inclusion and exclusion criteria was identified about the vascular injury related to midshaft clavicle fracture.

Buchanan et al. Published a case report in 2018 about acute subclavian artery occlusion related to midshaft clavicle fracture, which was treated with bypass graft alone. The treatment of the midshaft fracture was conservative. (18)

The case report describes traumatic subclavian artery occlusion secondary to midshaft clavicle fracture due to fall on outstretched hand. The patient was 73-year-old male with ischemic heart disease and previous coronary bypass surgery. In examination pulses from the upper limb were not palpable and there were reduced sensations of the arm and hand. Subclavian artery occlusion was diagnosed with CT angiogram nearby the midshaft clavicle fracture. In CTA there was 7cm filling. defect in the subclavian artery surrounded by hematoma, no active extravasation of the contrast material was seen. Treatment for the occlusion was started with low-molecular-weight-heparin.(18)

Figure 18. X-ray of the midshaft clavicle fracture

Figure 19. 3D reconstruction CT showing the filling defect of the subclavian artery near the fractured right clavicle. (18)

The surgical treatment was planned by vascular, orthopedic, and cardiothoracic surgeons. To avoid the direct approach of the artery and risk of moving the blood clot and causing bleeding from the subclavian artery it was decided to treat the fracture conservatively and to bypass the occlusion with saphenous vein graft. After the operation strong pulses from the upper limb were palpable and

sensory and motor function were normalized. After operation the upper limb was immobilized by sling for 4 weeks. In the follow-up the function of the upper limb normalized to pre-trauma level. (18)

In this case midshaft clavicle fracture was treated conservatively with good outcomes despite the vascular injury related to fracture. Open surgery was evaluated to be too risky because of the previous sternotomy patient had. Therefore, bypass surgery was chosen as treatment of the subclavian artery occlusion. Buchanan et al. argues that it seems logical to perform ORIF of the clavicle in case of direct repair of subclavian artery, but according to them it is unclear if the ORIF gives any benefits if alternative technique to direct repair, such as bypass, is used in case of subclavian artery occlusion with midshaft clavicle fracture. (18)

6.5. Skin tenting

Skin tenting refers to the situation in which fractured bone fragments threaten the integrity of the soft tissues above the fragment. (19) The skin tenting is diagnosed by inspection and palpation of the area around the suspected fracture. Traditionally immediate operative treatment is indicated because skin tenting possess high risk of open fracture situation.(7)

In literature search one article studying skin tenting as an indication for surgical treatment of midshaft clavicle fracture was identified.

A 2021 published retrospective cohort study by Zhang et al. aimed to identify factors associated with skin tenting in displaced midshaft fractures and analyze variation related surgeon in diagnosis of the skin tenting. The study was performed at two level I trauma centers with 396 patients with displaced midshaft clavicular fractures which were treated by 47 surgeons by ORIF. Patient variables included in the study were: age, BMI (body mass index), dominant upper extremity injury, diabetes mellitus, smoking status, American society of anesthesiologists physical status classification (ASA), fracture comminution, superior-inferior fracture shortening and medial-lateral fracture shortening. (19)

Skin tenting was diagnosed with 34 patients out of 396. Surgical treatment was performed for all 34 patients. Statistical analysis showed that fracture shortening (P=0.01), lower than mean BMI (P=0.001) and lower than mean ASA (P=0.04) were statistically significant with skin tenting

diagnosis. ASA classification fell out of significance in later analysis, showing the significance was most likely an error related to significance of the BMI. (19)

12 surgeons treated more than 10 displaced fractures. Surgeons treating these fractures were sports medicine surgeons, orthopedic trauma surgeons, hand and upper extremity surgeons. Depending on the surgeon there was variation from 0% to 41% in diagnosis of the skin tenting with the fracture. There was a statistically significant difference in the diagnosis of skin tenting among surgeons ($P<0.0001$). No statistical significance was found by subspecialty training. Also no significant difference was found among treating surgeons with regards to earlier mentioned patient variables. (19)

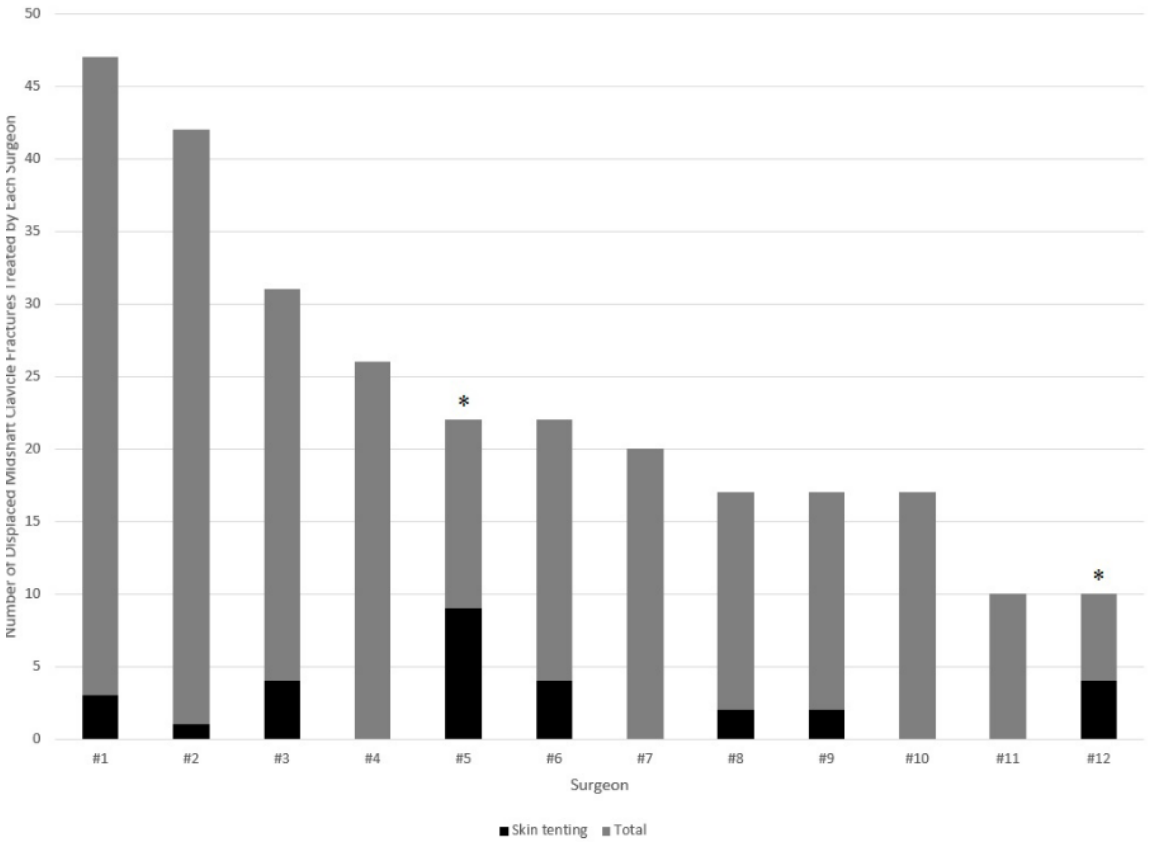


Figure 20. Bar graph. Full bar shows the number of fractures treated by each surgeon. The black areas of the bar represent the amount of skin tenting diagnosis made by each surgeon. (19)

The study shows that low BMI and shortening of the clavicle are independent risk factors of skin tenting. The more relevant finding of the study for this literature review is that Zhang et al. suggests that the diagnosis of the skin tenting seems to be subjective and clear language and reference standards for the diagnosis of the skin tenting are missing. Zhang et al. links the variation in the diagnosis to imprecision of the English language and possibility that some surgeons might have

different meanings for ‘’skin tenting’’. In some cases, it might refer to angular contour of the skin above the fracture and in other cases it might refer to bone fragments piercing the fascia into subcutaneous tissue or even impending necrosis of the overlying skin.(19)

6.6. shared decision making and surgeon preferences for treatment

6.6.1. Surgeon preferences

Oliveira et al. made a cross-sectional study using a questionnaire to find out preferences of Latin American orthopedic surgeons for treatment of the midshaft clavicle fracture. Study included a total of 344 answered questionnaires from Brazil, Argentina, Bolivia, Chile, Uruguay, Paraguay, Venezuela, Ecuador, Colombia, Mexico and Nicaragua. Study was conducted in Brazil and different nationalities in the study were grouped as Brazilians and foreigners. (20)

4.1% of the participants answered that conservative treatment was indicated in all types of midshaft clavicle fractures. The result was statistically significant with a p-value of 0.017. Conservative treatment was preferred to be done with sling as immobilization by 57.2% of the participants, by sling and figure-of-eight bandage by 22% and 16.9% preferred figure-of-eight bandage alone (p=0.012). (20)

95.8% of Brazilians and 88.2% of foreigners didn’t perform surgery in case of displaced fracture with cortical contact. If there was a shortening with fracture 84.7% of Brazilians and 70.6% of foreigners thought that the surgery is indicated. With skin tenting surgery was indicated for 91.6% of Brazilians and 60.3% of foreigners. In other indications there were no statistical differences between groups. Other indications included clinical deformity, segmental fracture, comminuted fracture, and displaced fracture with no cortical contact. These results are shown in **figure x.** (20)

	Total	Group		p value
		Latin American Society of Shoulder and Elbow Surgery	Brazilian Society of Shoulder and Elbow Surgery	
Displaced fracture with cortical contact				
No	310 (94.2)	60 (88.2)	250 (95.8)	p_2=0.035
Yes	19 (5.8)	8 (11.8)	11 (4.2)	
Displaced fracture without cortical contact				
No	56 (17.0)	13 (19.1)	43 (16.5)	p_1=0.606
Yes	273 (83.0)	55 (80.9)	218 (83.5)	
Fractures with shortening				
No	60 (18.2)	20 (29.4)	40 (15.3)	p_1=0.007
Yes	269 (81.8)	48 (70.6)	221 (84.7)	
Comminuted fracture				
No	199 (60.5)	37 (54.4)	162 (62.1)	p_1=0.250
Yes	130 (39.5)	31 (45.6)	99 (37.9)	
Segmental fracture				
No	184 (55.9)	37 (54.4)	147 (56.3)	p_1=0.778
Yes	145 (44.1)	31 (45.6)	114 (43.7)	
Imminent skin exposure				
No	49 (14.9)	27 (39.7)	22 (8.4)	p_1<0.001
Yes	280 (85.1)	41 (60.3)	239 (91.6)	
Evident clinical deformity (aesthetic aspect)				
No	232 (70.5)	47 (69.1)	185 (70.9)	p_1=0.776
Yes	97 (29.5)	21 (30.9)	76 (29.1)	

Figure 21. table showing surgical indication according to questionnaire answers from Latin American society of shoulder and elbow surgery and Brazilian society of shoulder and elbow surgery (20)

Study shows some heterogeneity in choosing the treatment method for midshaft clavicle fracture. Most of the surgeons in this study chose the surgical treatment in case of ‘’classical surgical indications’’ of the midshaft clavicle fracture. It is highlighted in the discussion of the study that the choice of treatment isn’t limited to only characteristics of the fracture, but also to expectations of the benefit from the treatment and perceived risk factors. (20)

6.6.2. Shared decision-making

The lack of clear treatment strategy for midshaft clavicle fractures offers an opportunity to shared decision making with patients. Medina Perez et al. did an online survey about preferred treatment methods for midshaft clavicle fracture and about shared decision-making preferences in 2020. (21)

The survey presented information about treatment options of midshaft clavicle fractures. After giving the information highlighting benefits of both surgical and conservative treatment, the respondents answered the questions related to their treatment preferences. Study included 235 participants. (21)

82.2% of respondents wanted to have physician involved in the decision-making process about the treatment and 17.8% wanted to make the decision on their own. 67.6% of the respondents wanting physician involvement preferred shared decision-making with the doctor and 14.6% wanted the doctor to make the decision about the treatment. 60.8% respondents opting for the shared decision-making wanted the doctor to give recommendations on the treatment and 39.2% wanted the doctor to provide information about treatment options before they make the treatment decision on their own. Surgery was chosen by 38.4% and no surgery by 61.6% of respondents when asked about the treatment decision. (21)

There were some statistically significant demographic factors affecting the treatment decision. 51.2% of the respondents younger than 33 years old chose no surgery and 48.8% chose surgery. In group consisting of respondents older than 33 years only 28.8% chose surgery and 71.2% chose no surgery. This difference between age groups was statistically significant with p value of 0.001. Also, there was statistical significance in difference between answers of married and unmarried respondents (p=0.006). 29.4% of unmarried people chose surgery over no surgery and 46.3% of married people chose surgery over no surgery. In other demographic factors such as race, income, education level or sex there was no statistical difference in treatment preferences. (21)

Factor	Odds ratio value	Lower limit	Upper limit	P-value
Age	0.97	0.94	0.99	0.007*
Male	1.70	0.96	3.00	0.067
Married	2.55	1.47	4.43	0.001*

Figure 22. Table showing clinical significance in age and marriage status in treatment preferences. (21)

Previous studies suggest that shared-decision making might improve the quality of life of the patient and lead to increased overall satisfaction with the treatment. According to this study most of the patients prefer shared decision-making over physician centered decision making. The variation in treatment preferences in the study might be related to older people avoiding risks and therefore to be inclined to choose more conservative treatment. (21)

6.7. Delayed union and nonunion of the fracture

Symptomatic nonunion is considered as surgical indication in midshaft clavicle fractures. The two most common complications of conservative treatment of these fractures are symptomatic nonunion and malunion of the clavicle.(4) Nonunion rate in adults with midshaft clavicle fracture treated by conservative measures are 7%-15%. Earlier studies show lower nonunion rates in conservative treatment because pediatric population, with significantly lower nonunion rates, were included in these studies (22)

2022 published study by Fox et al. compared functional outcomes in delayed union and nonunion to control group in which patients achieved union with conservative treatment. The comparison was done retrospectively by measuring QuickDASH, Oxford Shoulder Score (OSS) and EuroQol five-dimension summary index (EQ-5D). The secondary aim of the study was to find out if plate fixation of the fracture in case of delayed union or nonunion is cost-effective treatment measure. (23)

During the 10-year study period 110 plate fixations were performed to delayed union and nonunion. 60 of these patients completed the full follow-up and were included to study. Outcomes of these patients were compared to control group of 203 patients who underwent conservative treatment for the fracture. (23)

For the study union was defined as no pain perceived by the patient and radiographically identifiable callus at 3-month period after the injury. Nonunion was defined as no union in a 6-month period and delayed union as no union in 3months. (23)

QuickDASH score ($p<0.001$) and EQ-5D ($p=0.001$) were worse in the delayed and nonunion fixation group compared to control group. OSS were comparable between the groups ($p=0.125$). 20% of the patients were not satisfied with their outcome at the time of final follow-up, mean time to final follow-up from the operation was 4.1 years. 33% of patients had to change their main sport and 20% changed their occupation because of the injury. 10 patients had complications which required revision surgeries. Patients undergoing revision surgeries were less likely to be satisfied during the final follow-up. (23)

Parameter	Union following non-operative management $N = 60$	Delayed fixation cohort $N = 60$	p value
Age	38.4 (33.4–43.5)	43.1 (39.4–46.8)	0.140
Male	42 (70.0%)	36 (60.0%)	0.339
Smoker	8 (13.3%)	16 (26.7%)	0.109
Comminution	7 (11.7%)	12 (20.0%)	0.317
Manual job	17 (28.3%)	19 (31.7%)	0.842
Dominant side	23 (38.3%)	36 (60.0%)	0.100
QuickDASH	5.5 (3.4–7.6)	16.5 (11.6–21.5)	<0.001
Oxford Shoulder	43.8 (42.2–45.4)	41.5 (39.0–44.1)	0.125
EQ-5D	0.9073 (0.8714–0.9433)	0.7621 (0.6822–0.8421)	0.001

Figure 23. Results of from the final follow-up in regards of delayed fixation patients and conservatively treated patients with union(23)

Comparison between pre-operative and post-operative variables was performed to assess outcomes after the fixation was done. QuickDASH ($p<0.001$), OSS ($p<0.001$) and EQ-5D ($p<0.001$) were statistically significantly better in post-operative measurements. The cost-effectiveness was analyzed for delayed and non-union fixation of fracture. Showing it was a cost-effective treatment, cost per quality assessed life year (QALY) was 5624.62 pounds. (23)

Parameter	Pre-op cohort $N = 30$	Post-op cohort $N = 30$	p value
Age	49.4 (44.1–54.6)	44.4 (38.9–50.0)	0.192
Male	15 (50.0%)	22 (73.3%)	0.110
Smoker	12 (40.0%)	9 (30.0%)	0.589
Comminution	6 (20.0%)	4 (13.3%)	0.731
Manual job	7 (23.3%)	5 (16.7%)	0.748
Dominant side	17 (56.7%)	14 (46.7%)	0.606
QuickDASH	30.1 (21.7–38.5)	8.2 (4.7–11.6)	<0.001
Oxford Shoulder	33.5 (29.7–37.4)	45.3 (43.8–46.7)	<0.001
EQ-5D	0.6267 (0.5140–0.7394)	0.9093 (0.8681–0.9505)	<0.001

Figure 24. Comparison of the QuickDASH, OSS and EQ-5D between pre-op and post-op cohorts showing significantly improved scores(23)

According to this prospective cohort study operative fixation in case of delayed or nonunion of the midshaft clavicle fracture is cost-effective treatment associated with improved functional outcomes. The functional outcome is worse in this patient group compared to patients achieving union by conservative measures. (23)

7. Discussion

The aim of this literature review was to summarize the current literature about the treatment indications for the midshaft clavicle fracture in adults and to shed light on controversies related to these indications.

Various types of studies with different levels of evidence value were included in this literature review. Studies identified in the literature search included cohort studies, questionnaire studies, case reports, literature reviews and systematic reviews with meta-analysis, prospective and retrospective studies. All types of studies were included in the literature review to create a broader spectrum of the current situation in this field.

7.1. Clear surgical indications

The literature review shows that most of the studies published during the last 10 years seem to agree with some of the treatment indications for midshaft clavicle fractures being evidence based. Most of the studies mentioned shortening and displacement of the clavicle, neurovascular injuries, open fractures, skin tenting, nonunion and floating shoulder as indications for surgical treatment. But in the literature search there were no published studies identified from the previous 10 years studying open fractures, nervous structure injuries or floating shoulder as a surgical indication. This could be hypothesized to be because these indications are seen as solid, evidence-based indications and no research has been done to evaluate them further in recent years. To evaluate this hypothesis further the literature review should have included older studies than the current time scope allowed.

The biggest portion of the studies identified from the databases were related to shortening and displacement of the midshaft clavicle fracture. A total of 8 studies were identified related to

shortening and displacement as a treatment indication. The functional outcomes related to surgical and conservative treatment especially seem to be highly active research field. Studies included in this literature review did not agree that the shortening of more than 2 cm should be considered as a surgical indication. Study by Woltz et al showed similar functional outcomes in surgical and conservative treatment of such fracture, also similar findings were done by Eden et al. On the other hand, a study by Hulsmans et al showed excellent functional outcomes in surgical treatment in displaced midshaft fractures. Micheloni et al also found no significant difference in functional outcomes between surgical and conservative treatment and therefore suggested individualized treatment decisions according to patient characteristics.

Delayed union and nonunion after conservative treatment were also mentioned in many of the studies as surgical treatment indication. One publication studying this indication was identified for this literature review. A study by Fox et al. showed that surgical treatment of nonunion was both cost effective and it was associated with improved functional outcome. No studies against this indication were identified and therefore it seems like current evidence supports nonunion as a surgical indication.

7.2. Controversies

A major problem using the shortening as an indication for surgical treatment seems to be the methods of how the shortening is measured. Ergisi et al showed in their study that the assumption that the clavicles are symmetrical is invalid and therefore methods using the contralateral clavicle for measurement of the shortening doesn't give accurate data about the shortening. Also imaging modalities used to calculate shortening are not equal. Archer et al showed in their study that plain x-ray measurements don't reliably show shortening of the clavicle fracture compared to computed tomography. On the other hand, Öztürk showed in their study comparing 3D-VR to plain X-rays that there are two methods to measure shortening in plain X-ray that has similar accuracy to computed tomography measurements. It seems that more standardization is needed in measurement of the clavicle shortening to accurately use it as a treatment indication.

Similar problem as shortening measurements was identified also in the literature about skin tenting as an indication for surgical treatment. Zhang et al. found out in their study that there is significant variation between surgeons in giving the diagnosis of the skin tenting related to midshaft clavicle fracture. The clear standard for this diagnosis is missing and therefore the diagnosis is subjective and depends on the surgeon. It's still seen as a risk for open fracture situation and therefore seems

to be logical surgical indication, but it seems like more precise language for diagnosis is needed to have better standardization.

Although majority of the published studies named neurovascular injury as an absolute indication for surgical treatment in midshaft clavicle fractures, only one study about this indication was identified for this literature review. The case report showed that the conservative management of the fracture in midshaft clavicle fracture with vascular injury is possible when direct vascular repair is not used. One case report is not enough to say that neurovascular injury should not be used as surgical indication, but it shows that conservative management is also possible. More studies are needed to evaluate outcomes in such practice.

The controversies in the indications and unconclusive understanding of the optimal treatment methods also opens possibilities to practice more patient friendly medicine for example in the form of shared decision making with the patient. A questionnaire study by Medina Perez et al. showed that most of the patients prefer shared decision making over physician centered decision making. In situations where literature is not able to provide superiority of one treatment modality over another, including the patient in decision making might lead to improved satisfaction with the treatment. A study by Oliveira et al. investigating surgeon preferences on the treatment modalities showed that there is heterogeneity between surgeons when choosing the treatment modality. This might be related to subjectivity of the indications, as discussed previously, and to personal experience on the outcomes of treatment. It shows that more standardization might be needed when it comes to indications. Also, this subjectivity could be used to include the patients in the decision making.

7.3. Conclusion

To conclude this literature review summarized results of the modern studies about treatment indications of the midshaft clavicle fractures in the adults. The literature shows some controversies related to diagnostics of conditions like shortening or skin tenting and the optimal treatment method of different types of fractures is still not clear. The studies included in this literature review show good outcomes in both surgical and conservative treatment of the midshaft clavicle fractures and many authors suggest individualized treatment decisions according to patient characteristics. More studies are needed to improve the standardization of the indications and to definitively determine the optimal set of indications for surgical and conservative treatment of these fractures.

8. List of figures

9. List of references

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